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THE CALIFORNIA SEA LION: SKULL GROWTH
AND A COMPARISON OF TWO POPULATIONS

By

Robert T. Orr and Jacqueline Schonewald
California Academy of Sciences, San Francisco, California 94118

and

Karl W. Kenyon
*Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service,
Seattle, Washington 98115*

ABSTRACT: Teeth and cranial characters denoting the age of 121 male California sea lion skulls (76 from the Pacific coasts of California and Baja California and 45 from the Gulf of California) were studied. Ages ranged from 1 to about 15 years. Great individual variations in cranial characters were found, but no significant differences between the two populations were revealed. The relation between age and suture closure was fairly constant until about age 15 when all 9 sutures studied are completely closed. In length and width, skull growth continues until about age 10 years. Sagittal crest growth commences in the 5th year and ceases in about the 10th year.

INTRODUCTION

The California sea lion (*Zalophus californianus californianus*) in the eastern North Pacific breeds on suitable offshore islands from San Miguel, the northernmost of the California Channel Island group, south along the west coast of Baja California to the San Benitos Islands, and on certain islands in the Gulf of California and along the mainland of Mexico, south possibly to Mazatlán.

Between 1964 and 1968, in the months of April, June, August, and November, Orr made six trips to islands in the Gulf to secure data on the sea lion pop-

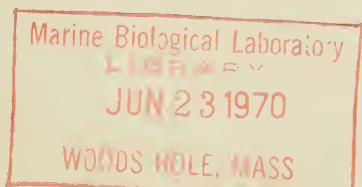


TABLE 1. Localities, from north to south, in the Gulf of California at which *Zalophus californianus* was observed by the authors between 1960 and 1968.

Locality ¹	Date	Number	Composition
Isla Coloradito	24 Nov. 1960	500-600	Both sexes, all ages
Bahía San Luis Gonzaga	10 Nov. 1965	75	Both sexes, all ages
Isla Granite	20 Apr. 1966	1,000+	Both sexes, all ages
Isla Angel de la Guarda	21 Apr. 1966	1,000+	Unknown, observed from a distance
Bahía de los Angeles	13 Nov. 1965	75	Both sexes, all ages
Isla Partida (Norte)	28 Apr. 1966	485	30% ad. ♂♂, 30% subad. ♂♂, 40% ♀♀ and imm.
Isla San Esteban	27 Apr. 1966	151	125 ad. ♂♂, 26 ♀♀ or imm. ♂♂
Isla San Pedro Mártir	25 Apr. 1966	2,700+	Both sexes, all ages
"	29 Apr. 1968	300+	Unknown
Isla Santa Catalina	24 June 1964	several	No breeding activity
Isla Las Animas	27 June 1964	8	5 ad. ♂♂, 3 ♀♀ or imm. ♂♂; no breeding activity
"	12 Aug. 1965	30	Both sexes, all ages
"	7 Oct. 1964	500	Unknown ²
Los Islotes	30 June 1964	187	12 ad. ♂♂, incl. 3 dominant bulls, 2 subad. ♂♂, 173 ♀♀ + imm. Breeding?
"	10 Aug. 1965	190±	Several ad. ♂♂ incl. 4 dominant bulls, 150 ♀♀ with large nipples, and imm.
"	4 Oct. 1964	200-300	Unknown ²
Isla Cerralvo	25 Apr. 1966	75+	6-8 Ad. ♂♂, large number of ♀♀, some imm. ♂♂
Cabo San Lucas	8 Feb. 1965	1	Ad. ♂

¹Cf. Lindsay, 1962.

²Observed by George Tsegeletos.

ulation of that area. From 3 to 15 days per visit were spent in the field. Kenyon observed sea lions and collected skulls in the Gulf in November 1960 and February 1965.

California sea lions were observed from Isla Coloradito in the north to Cape San Lucas in the south (table 1). Mixed populations of males, females, and immatures were noted at essentially all times. This suggested a difference in behavior between the Gulf population, which may be rather sedentary, and the Pacific coastal population, in which the majority of the males move north of the areas occupied by the females and young after the breeding season (Orr and Poulter, 1965; Peterson and Bartholomew, 1967). Fully adult males move farthest north, regularly at least to Sea Lion Caves near Florence, Oregon (Kenyon and Scheffer, 1962). On only one occasion, at San Esteban Island on 27 April 1966, was there some indication of at least local sexual segregation. On that date a group composed of 125 males and 26 other individuals, which might have been females or immature males, was observed hauled out together.



FIGURE 1. A section of canine tooth of a *Zalophus californianus* male showing annual growth lines. University of California photograph by Alan Donaldson. Courtesy of Richard S. Peterson.

TABLE 2. Age composition of 35 California sea lion skulls based on growth layers of an upper canine.

Age		Age	
Years	Specimens Number	Years	Specimens Number
1	1	9	3
2	2	10	4
3	2	11	5
4	1	12	2
5	1	13	3
6	1	14	1
7	3	15	4
8	2		

The authors made a special effort to collect skulls, primarily those of adult males. Our objectives were: (1) to determine if there were any cranial differences between the Gulf of California population and that occurring on the Pacific coastal side of Baja California and the California coast, and (2) to study skull growth and suture closure in relation to age.

TABLE 3. Comparison of cranial measurements of adult male skulls (suture ages 25-36) of *Zalophus californianus* from the Gulf of California (G) and Pacific coasts of Baja California and California (P).

Measurement	Population	N	Range in mm.	Mean	CV
Condylbasal length	P	44	262-300	284.38 ± 1.42	3.30
	G	28	264-302	286.03 ± 1.95	3.60
Gnathion to posterior end of nasals	P	44	92.5-113	104.42 ± 0.70	4.50
	G	28	92.5-115	103.82 ± 1.15	5.83
Gnathion to posterior border of postglenoid process	P	45	199-226	215.40 ± 1.10	3.42
	G	28	201-229	218.00 ± 1.52	3.68
Gnathion to posterior border of preorbital process	P	44	93-108	101.12 ± 0.52	3.42
	G	29	88-108	99.28 ± 0.93	5.06
Breadth at preorbital processes	P	38	75.5-95.5	81.82 ± 0.78	5.86
	G	24	67.0-90.0	82.12 ± 1.02	6.10
Interorbital constriction	P	45	36.0-59.5	46.57 ± 0.56	8.15
	G	31	39.0-52.5	45.59 ± 0.57	7.01
Breadth at supraorbital processes	P	43	56.5-87.0	68.99 ± 1.08	10.29
	G	27	50.5-82.5	65.68 ± 1.48	11.72
Zygomatic breadth	P	44	140-171	157.75 ± 1.05	4.41
	G	26	136-171	157.15 ± 1.46	4.74
Mastoid breadth	P	44	127-164	143.20 ± 0.36	5.30
	G	30	123-153	142.33 ± 0.43	5.26
Sagittal crest*	P	45	11-34	25.48 ± 0.81	21.35
	G	32	13-36.5	26.87 ± 1.00	21.32

* This measurement is included here to show that it is equally variable in both populations.

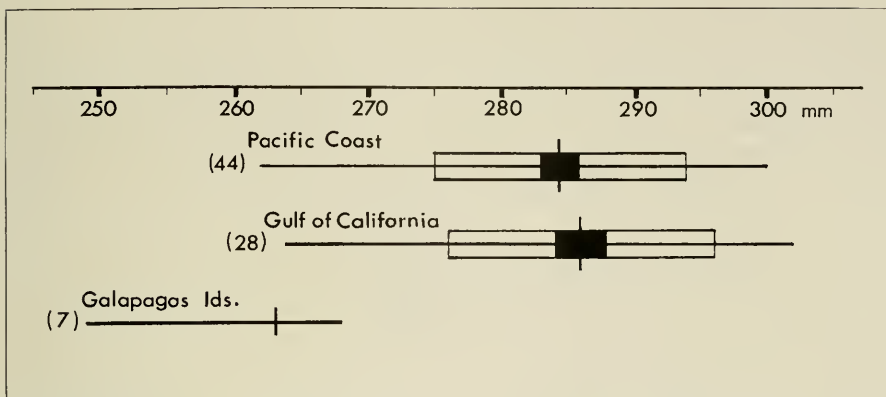


FIGURE 2. Statistical analysis of the condylobasal length in adult male skulls (suture index 25-36) of *Zalophus c. californianus* from the Pacific coast and Gulf of California. Horizontal lines represent observed range, open rectangles the standard deviation, and the solid black is twice the standard error of the mean. For further comparison the range and mean of a small sample of *Zalophus c. wolfebacki* is shown. The number of specimens used is given in parentheses.

MATERIALS AND METHODS

SPECIMENS EXAMINED. A total of 121 skulls of males (76 from the Pacific coast of California and Baja California and 45 from the Gulf of California, Mexico) were studied:* California: Marin County: Point Reyes Peninsula, 1 (CAS); San Francisco County: San Francisco, 2 (RB); San Mateo County: Pacifica, 1 (RB); Año Nuevo Island and Año Nuevo Point, 42 (RB, 31; CAS, 11); Santa Cruz County: Waddell Beach, 7 (RB); Santa Barbara County: Santa Cruz Island, 15 (CAS, 14; CAS-SU, 1); Mexico: Baja California: Isla San Martín, 2 (LACM); vicinity of Bahía de Sebastián Viscaíno, 4 (LACM, 2; SDNHM, 2); Bahía Tortugas, 2 (SDNHM); Puertecitos, 1 (LACM); Isla Coloradito, 17 (KWK); Isla Granite, 3 (SDNHM); Isla Angel de la Guarda, 5 (CAS, 1, SDNHM, 4); Bahía de los Angeles, 2 (CAS); Isla Carmen, 1 (CAS); Isla Santa Cruz, 1 (SDNHM); Isla San Diego, 1 (SDNHM); Isla San José, 1 (CAS); Isla Espíritu Santo, 1 (CAS); Isla Cerralvo, 1 (CAS); Rancho Chenque, 1 (SDNHM); Sonora: Isla San Jorge, 3 (LACM); Isla San Esteban, 2 (CAS); Isla San Pedro Mártir, 5 (CAS, 4; SDNHM, 1). Most of the skulls were from animals that had recently died. A few were weathered skulls which were found on beaches.

* Abbreviations used: CAS—California Academy of Sciences collection; RB—Raymond Bandar private collection; CAS-SU—Stanford University collection, now incorporated in CAS collection; LACM—Los Angeles County Museum collection; SDNHM—San Diego Natural History Museum collection; KWK—Karl W. Kenyon collection, now incorporated in CAS collection.

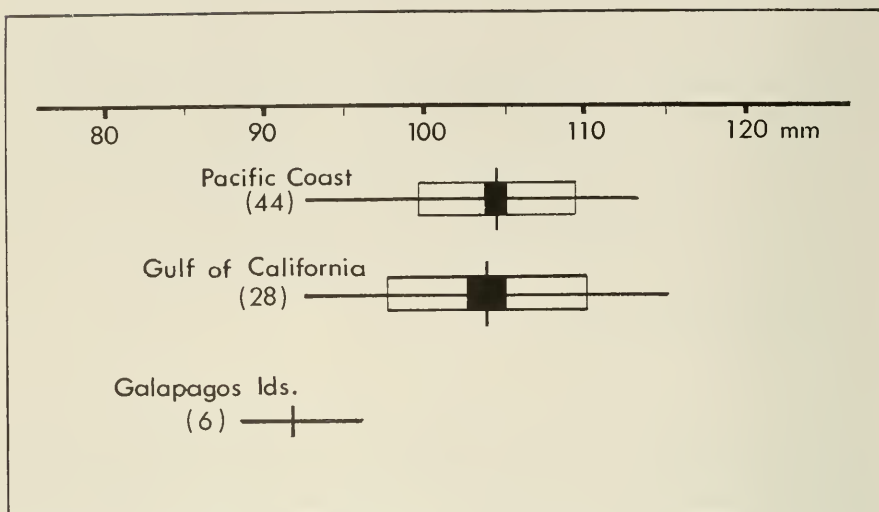


FIGURE 3. Statistical analysis of the skull from gnathion to posterior end of nasals of adult males from Pacific coast and Gulf of California populations of *Zalophus c. californianus*. The range and mean of a small sample of *Zalophus c. wolfebaeki* are shown for further comparison.

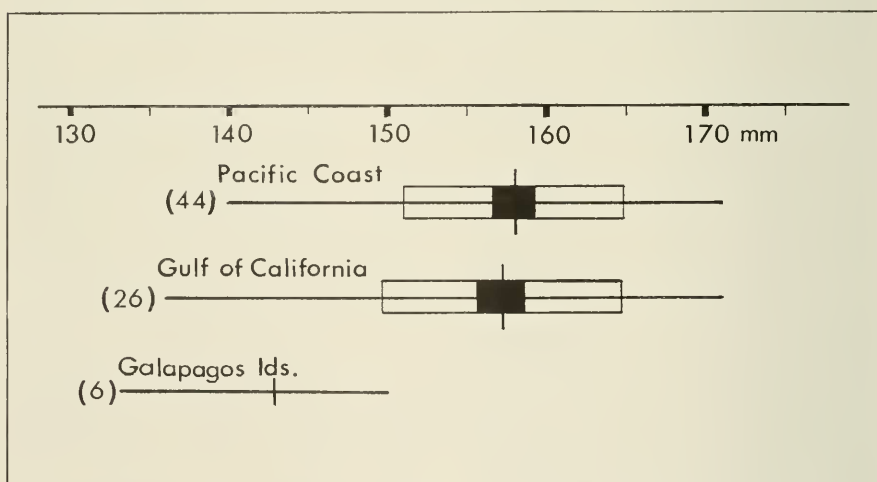


FIGURE 4. Statistical analysis of zygomatic breadth of skull of adult males from Pacific coast and Gulf of California populations of *Zalophus c. californianus*. The range and mean of a small sample of *Zalophus c. wolfebaeki* are shown for further comparison.

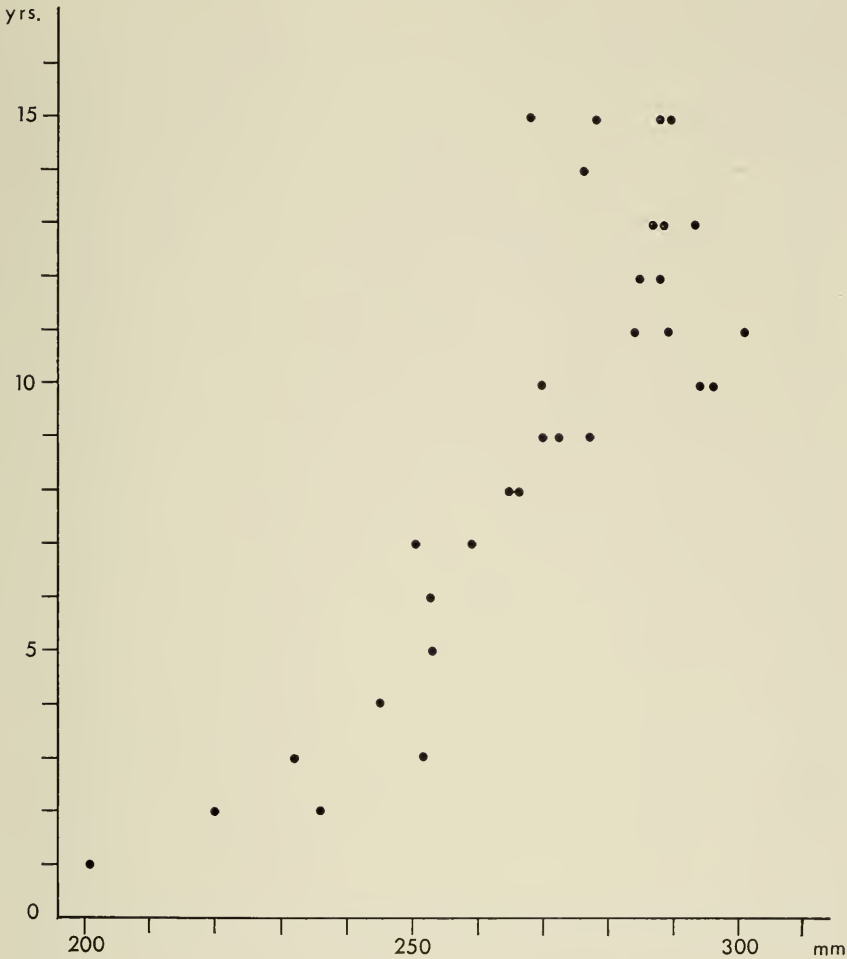


FIGURE 5. Condylobasal length of 31 skulls of *Zalophus c. californianus* males, selected to show a wide range in age, and plotted against approximate known age determined by number of annual tooth rings.

AGING TECHNIQUE. Scheffer (1950) demonstrated that annual growth layers could be counted in the teeth of fur seals (*Callorhinus ursinus*). The teeth of sea lions exhibit similar growth layers (fig. 1). For the present study we selected 35 skulls, representing a broad spectrum of ages. A single upper canine was removed from each, and sectioned and polished to reveal the growth layers. Ages, based upon tooth ring counts, are accurate only to within a year or two. The age groups represented are shown in table 2.

SUTURE INDEX. All specimens were suture indexed according to the method

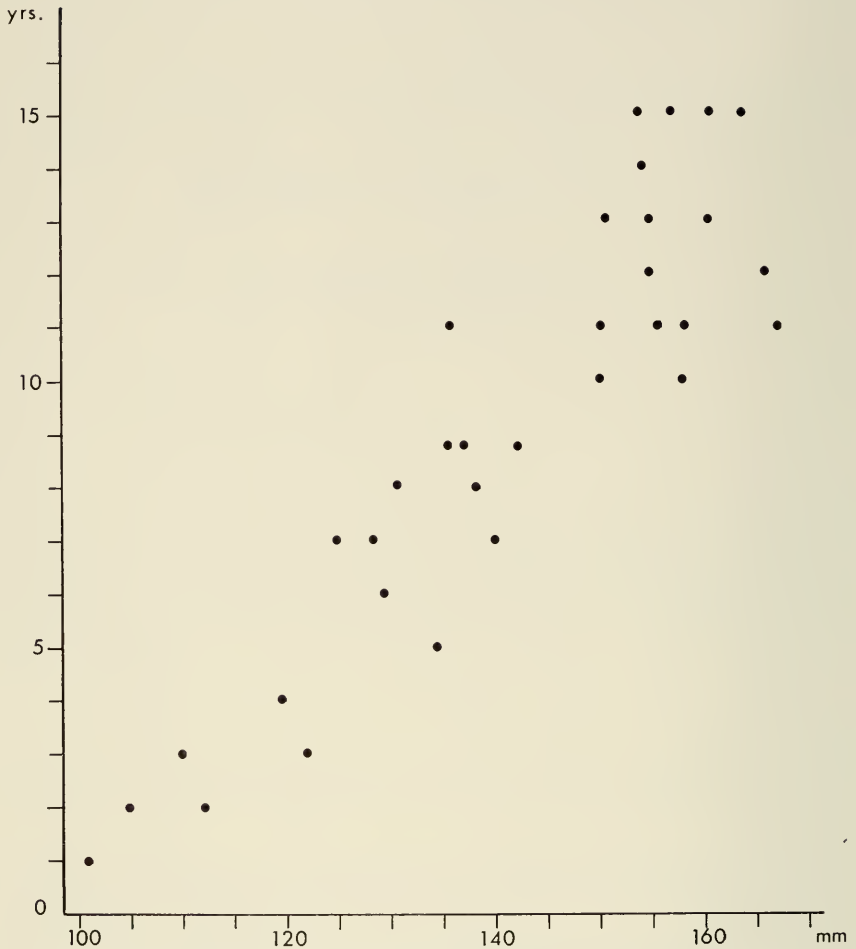


FIGURE 6. Zygomatic breadth of 33 skulls of *Zalophus c. californianus* males, selected to show a wide range in age, and plotted against approximate known age determined by number of annual growth rings.

used by Sivertsen (1954), which is a modification of that first suggested by Doult (1942). Nine sutures were used. These are as follows: I, occipito-parietal; II, squamoso-parietal; III, interparietal; IV, interfrontal; V, coronal; VI, basioccipito-basisphenoid; VII, maxillary; VIII, basisphenoid-presphenoid; IX, premaxillary-maxillary. A value of 1 to 4 is given on the basis of degree of closure: 1, open; 2, less than half closed; 3, more than half closed; and 4, completely closed. An immature skull, therefore, could not have an index of less than 9 and a mature skull of more than 36.

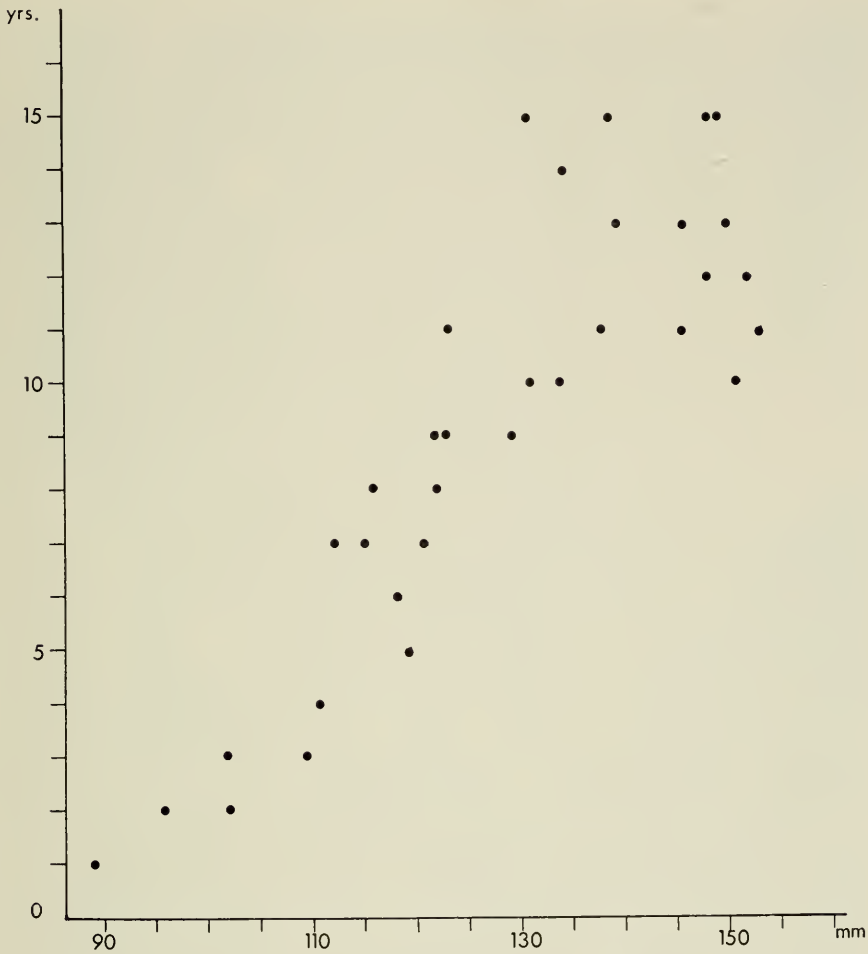


FIGURE 7. Mastoid breadth of 33 skulls of *Zalophus c. californianus* males, selected to show a wide range in age, and plotted against approximate known age determined by number of annual growth rings.

MEASUREMENTS. Ten cranial measurements were taken, as shown in table 3. These were submitted to statistical analysis. Studies of individual variation and variations between populations were made.

DISCUSSION AND CONCLUSIONS

GEOGRAPHICAL VARIATION. Analysis of the 10 cranial measurements showed great individual variability, but there were no significant statistical differences in these characters between the California sea lion population of the Gulf and



FIGURE 8. A group composed largely of adult male California sea lions hauled out on Año Nuevo Island. Note the prominent crest on the head, which is correlated with the development of the sagittal crest on the skull. Photographed 25 May 1961 by R. T. Orr.

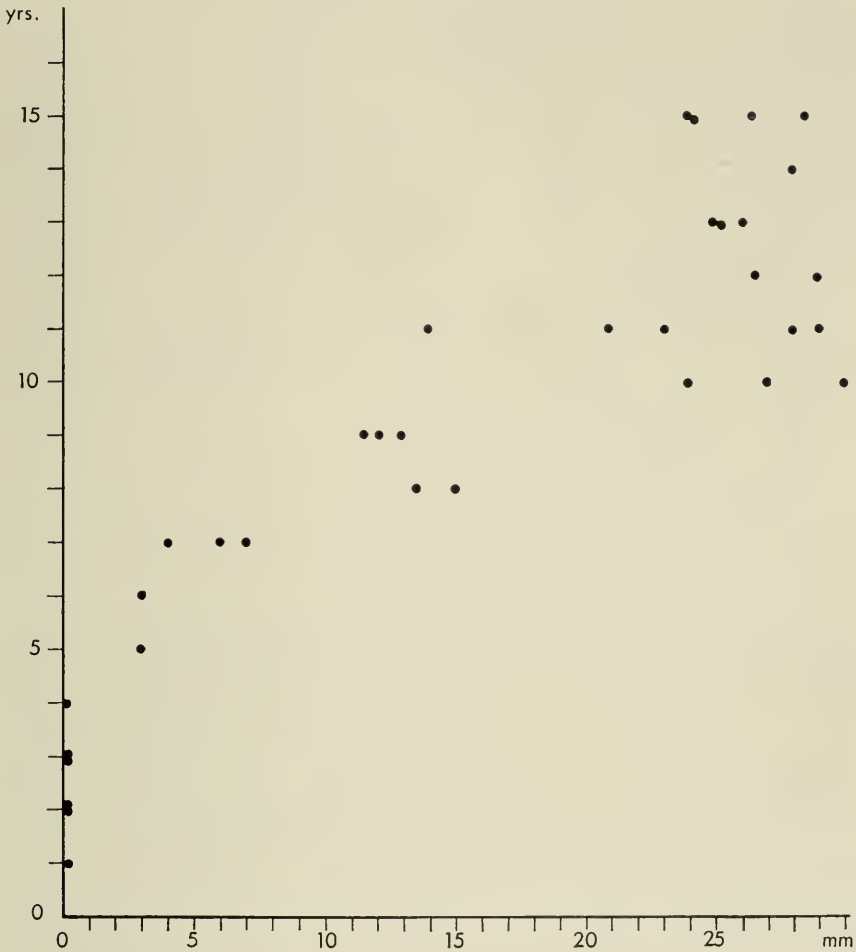


FIGURE 9. Height of sagittal crest on skull of 34 specimens of *Zalophus c. californianus* males, selected to show a wide range in age, and plotted against approximate known age determined by number of annual growth rings.

that of the Pacific coast. Three measurements (condylobasal length, gnathion to posterior end of nasals, and zygomatic breadth) which were among those with the lowest coefficient of variability are shown in figures 2, 3, and 4. By way of comparison, the range and mean for these same measurements in six adult skulls of *Zalophus c. wollebaeki* from the Galápagos Islands are included.

SKULL GROWTH AND SUTURE CLOSURE. The indicated ages of 35 animals were plotted against four measurements: condylobasal length, zygomatic breadth, mastoid breadth, and height of sagittal crest. These measurements indicate

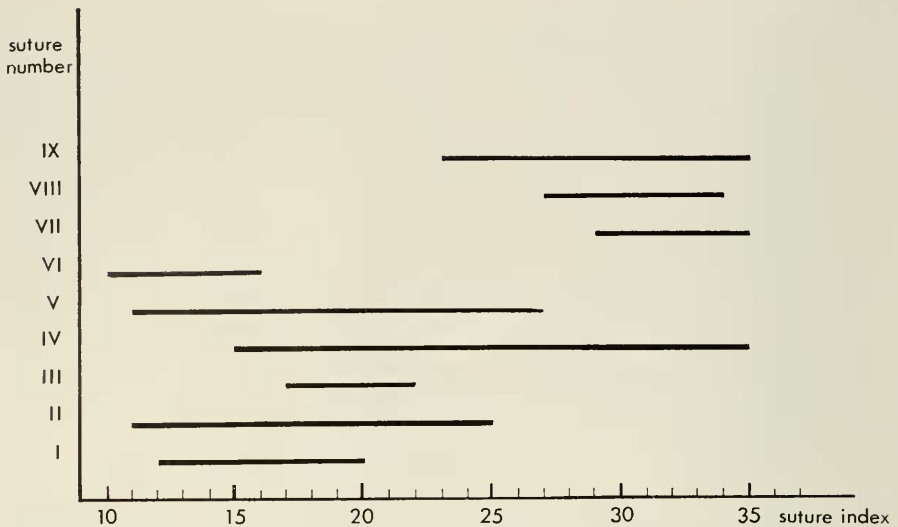


FIGURE 10. Suture index from beginning to end of closure of sutures I to IX.

growth until about the 10th year of life, following which there is essentially no marked change (figs. 5, 6, and 7). Similar findings for the Steller sea lion (*Eumetopias jubata*) male were reported by Fiscus (1961). Although it is difficult to obtain an accurate measurement of the height of the sagittal crest, it was used because it is one of the best indicators of age in male California sea lions (fig. 8). No crest is apparent on 2-, 3-, and 4-year-old individuals. A small crest appears in the 5th year and from then on the crest increases in height up to the 10th year of life, after which little change is evident (fig. 9).

The time at which suture closure begins as well as the length of time involved depend upon the suture. Sutures I, II, V, and VI are the first to show signs of closing. Sutures VII, VIII, and IX are last to begin closure. The greatest length of time required for closure is shown by sutures IV and V, the shortest time by sutures III, VI, and VII (fig. 10).

By plotting the known tooth age in 35 skulls of male *Zalophus californianus* against the suture index for each specimen, it is evident that there is a fairly constant correlation between age and suture index; the latter increases gradually until the 15th year of life, at which time all nine sutures are completely closed (fig. 11).

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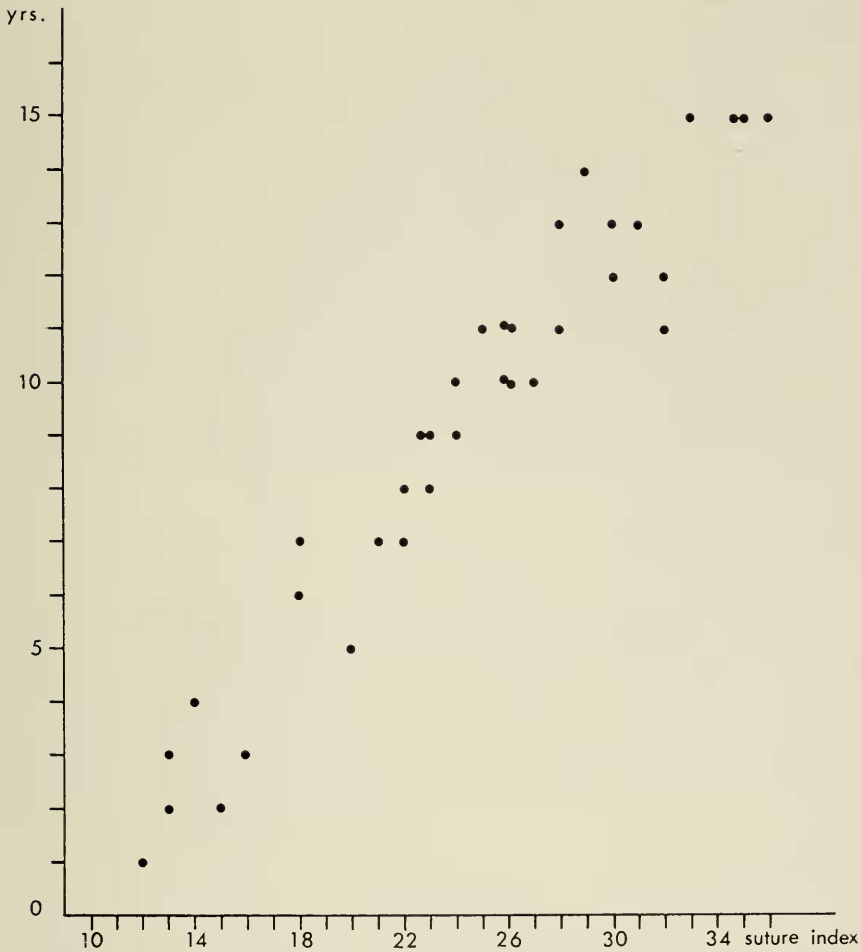


FIGURE 11. Suture index of 35 skulls of *Zalophus c. californianus* males, selected to show a wide range in age, and plotted against approximate known age determined by number of annual growth rings.

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